Accident Investigation

U.S. Department of the Interior
National Mine Health and Safety Academy
Safety Manual No. 10

I 69.8/2:10
Item 644-A

SAFETY MANUAL NO. 10

ACCIDENT INVESTIGATION

013836

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5/11 c24.019-00030-6
* $1.90

UNITED STATES DEPARTMENT OF THE INTERIOR

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NATIONAL MINE HEALTH AND SAFETY ACADEMY

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PREFACE

This is one of a series of pamphlets prepared by the technical staff of the National Mine Health and Safety Academy to acquaint the reader with a subject relating to mine health and safety. This manual deals with the technical aspects of accident investigations. The administrative requirements for conducting investigations are specified in 30 CFR 50. Because much of this manual contains general information, it can be used by workers in other industries as well as by students and others interested in mining and mine-related activities. A list of references (bibliography) is included for those interested in additional information on accident investigation procedures.

Other manuals available in this series are listed on the inside back cover. Individual copies may be obtained from any training center of the Mine Safety and Health Administration or from the National Mine Health and Safety Academy, Beckley, West Virginia.

Beckley, West Virginia
July 1978

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Accidents are part of a broad group of events that adversely affect the completion of a task. This group of events is known as incidents.

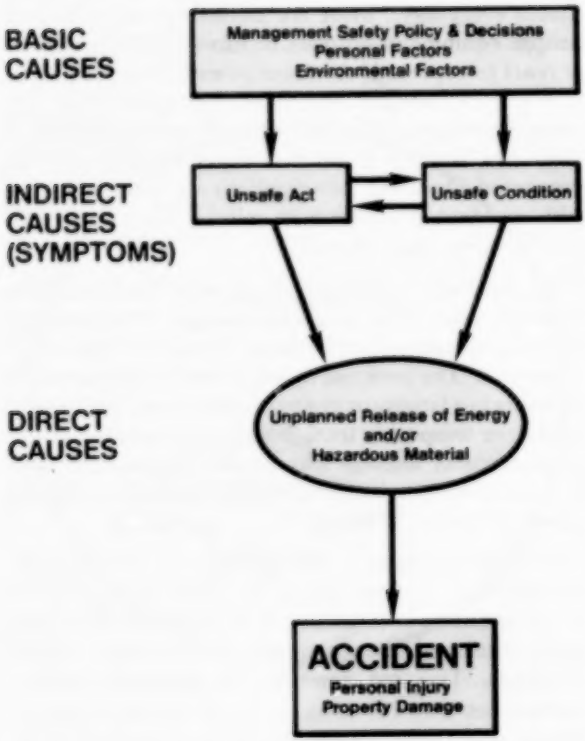
INTRODUCTION

Thousands of accidents occur throughout the United States every day. Most are caused by the failure of people, equipment, supplies, or surroundings to behave or react as expected. Accident investigations are made to determine how and why these failures occurred. By using the information gained through an investigation, a similar or perhaps more disastrous accident may be prevented. Accident investigations are thus conducted with accident prevention in mind. They are **NOT** conducted to place blame.

An accident is any unplanned event that results in personal injury or in property damage. The personal injury is considered minor when it requires little or no treatment. The personal injury is considered serious if it results in a fatality or in a permanent total, permanent partial, or temporary total (lost-time) disability. Similarly, property damage may be minor or serious. All accidents should be investigated regardless of the extent of injury or damage.

Accidents are part of a broad group of events that adversely affect the completion of a task. This group of events is known as incidents. For simplicity, the procedures discussed in subsequent sections refer only to accidents. They are, however, also applicable to incidents.

This Safety Manual introduces the reader to basic accident investigation procedures and describes the accident analysis techniques that can be used. Safety Manual No. 4, **Accident Prevention**, contains background information on accident investigation and related topics of interest to mining personnel. Technical specialists may wish to consult the other references listed in the bibliography.



A detailed analysis of an accident will normally reveal three cause levels: basic, indirect, and direct.

ACCIDENT PREVENTION

Accidents are usually complex. An accident may have 10 or more individual events that can be considered causes. A detailed analysis of an accident will normally reveal three cause levels: basic, indirect, and direct. At the lowest level, an accident results only when a person or object receives an amount of energy or hazardous material that cannot be absorbed safely. This energy or hazardous material is the DIRECT CAUSE of the accident. The direct cause is usually the result of one or more unsafe acts or unsafe conditions, or both. These unsafe acts and conditions are the INDIRECT CAUSES or symptoms. In turn, indirect causes are usually traceable to poor management policies and decisions, or to personal or environmental factors. These are considered the BASIC CAUSES. Examples of direct, indirect, and basic causes are listed in the appendices.

In spite of their complexity, most accidents can be prevented by eliminating one or more causes. Accident investigations are conducted in an attempt to determine not only what happened, but also how and why. The information derived from these investigations can prevent recurrence of similar or perhaps more disastrous accidents. An accident investigator is thus interested in each event as well as in the sequence of events that led to an accident.

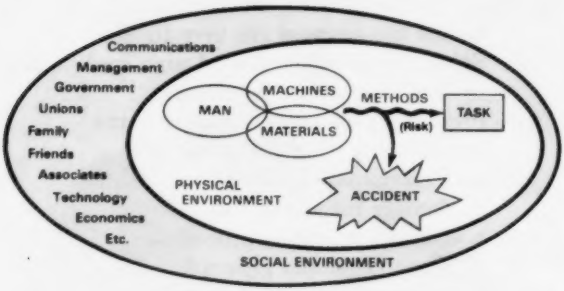
The accident type is also important to the investigator. The recurrence of accidents of a particular type or those with common causes indicates areas needing special accident prevention emphasis. Accident types are also listed in the appendices.

An accident investigator not only determines WHAT happened, but also HOW and WHY the accident occurred.

INVESTIGATIVE PROCEDURES

The actual procedures used in a particular investigation depend on the nature and results of the accident. The administrative procedures to be followed (such as those contained in 30 CFR 50) are prescribed by the agency having jurisdiction over the location. In general, responsible officials will appoint an individual to be in charge of the investigation. Most if not all of the following steps are then used by this individual:

1. Define the scope of the investigation.
2. Select the investigators. Assign specific tasks to each (preferably in writing).
3. Present a preliminary briefing to the investigating team, including
   a. Description of the accident, with damage estimates.
   b. Normal operating procedures.
   c. Maps (local and general).
   d. Location of the accident site.
   e. List of witnesses.
   f. Events that preceded the accident.
4. Visit the accident site to obtain updated information.
5. Inspect the accident site.
   a. Secure the area. Do not disturb the scene unless a hazard exists.
   b. Prepare the necessary sketches and photographs. Label each carefully and keep accurate records.
6. Interview each victim and witness, as well as those who were present before the accident and those who arrived at the site shortly after the accident. Keep accurate records of each interview. A tape recorder may be used if desired and if approved by each individual.



Most accidents are caused by the failure of people, equipment, supplies or surroundings to behave or react as expected.

7. Determine
   a. **What** was not normal prior to the accident.
   b. **Where** the abnormality occurred.
   c. **When** it was first noted.
   d. **How** it occurred.
8. Analyze the data obtained in step 7. Repeat any of the prior steps, if necessary.
9. Determine
   a. **Why** the accident occurred.
   b. A likely sequence of events and probable causes (direct, indirect, basic).
   c. Alternative sequences.
10. Evaluate each sequence against the data from step 7.
11. Determine the most likely sequence of events and the most probable causes.
12. Conduct a post-investigation briefing.
13. Prepare a summary report, including the recommended actions to be taken to prevent a recurrence. Distribute the report in accordance with applicable instructions.

Note that an investigation is not complete until all data have been analyzed and a final report is prepared. In practice, the investigative work, data analysis, and report preparation proceed simultaneously over much of the time spent on the investigation.

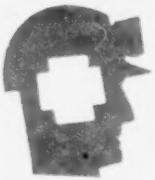
Personal protective equipment is often needed in conducting accident investigations.

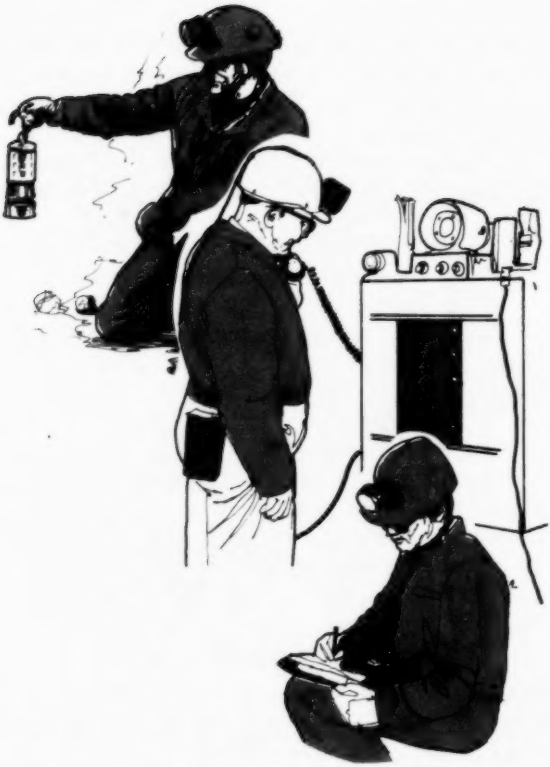
EQUIPMENT AND SUPPLIES

The equipment and supplies used in conducting a particular investigation depend on the nature and location of the accident. The following items are useful on many occasions:

1. Suitable clothing and protective equipment (coveralls, jacket, hard hat, safety glasses, boots, etc.)
2. Credentials; travel authorization.
3. Cash, credit cards, purchase orders.
4. Bound notebook.
5. Tape recorder (preferably miniature).
6. Camera and film.
7. Barometer.
8. Anemometer.
9. Tape measure or rule.
10. Sample bottles, tags, and adhesive tape.
11. Pencils, chalk, and cord.
12. Report forms.
13. Gas detectors.
14. First aid kits.
15. Carrying bag(s).
16. Portable lamp or flashlight.

Additional equipment may be needed on occasion. This need will usually be obvious during the preliminary briefing phase of the investigation.





Evidence is gathered from any of a number of sources during the course of an investigation.

FACT-FINDING

Evidence is gathered from numerous sources during an investigation. Information is obtained from witnesses and reports as well as by observation. Witnesses should be interviewed as soon as possible after an accident. Similarly, the accident site should be inspected before any changes occur. Photographs and sketches should be made of the accident scene, and all pertinent data should be recorded on maps. Copies should be obtained of all relevant reports. Documents containing normal operating procedures, flow diagrams, maintenance charts, or reports of difficulties or abnormalities are particularly useful. Complete and accurate notes should be kept in a bound notebook. Pre-accident conditions, the accident sequence, and post-accident conditions should be recorded. In addition, the location of victims, witnesses, machinery, energy sources, and hazardous materials should be documented.

In some investigations, a particular physical or chemical law, principle, or property is needed to explain a sequence of events. Such laws should be included in the notes taken during the investigation or in the subsequent analysis of data. In addition, data should be gathered during the investigation that may lend itself to analysis by these laws, principles, or properties. If an extended discussion is needed in the final report, it can be included in an appendix.

In conducting an interview, a group spokesman should be appointed, and sketches and diagrams should be used to assist the witness.

INTERVIEWS

In general, interviews should be conducted by experienced personnel. If possible, the team assigned to this task should include an individual with a legal background. In conducting interviews, the team should:

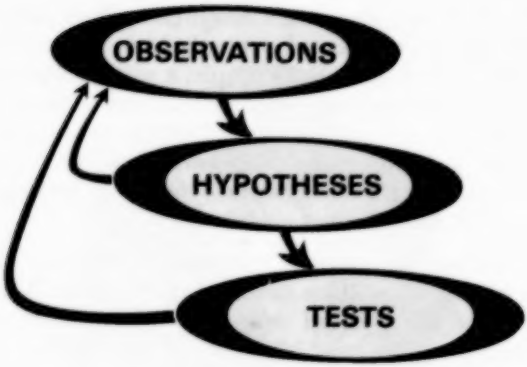
1. Appoint a speaker for the group.
2. Get preliminary statements as soon as possible from all witnesses—those who arrived on the scene shortly after or shortly before the accident.
3. Locate the position of each witness on a master chart (including the direction of view).
4. Arrange for a convenient time and place to talk to each witness.
5. Explain the purpose of the investigation (accident prevention) and put each witness at ease.
6. Listen, let each witness speak freely, and be courteous and considerate.
7. Take notes without distracting the witness. Use a tape recorder only with the consent of the witness.
8. Use sketches and diagrams to assist the witness.
9. Emphasize areas of direct observation. Hearsay should be labeled accordingly.
10. Be sincere and do not argue with the witness.
11. Record the exact words used by the witness to describe each observation. Do not "put words into a witness' mouth."
12. Word each question carefully and be sure the witness understands.
13. Identify the qualifications of each witness (name, address, occupation, years of experience, etc.).
14. Supply each witness with a copy of his or her statements. Signed statements are desirable.

A witness who has had a traumatic experience may not be able to recall the details of an accident.

After all witnesses have been interviewed, the team should analyze each witness' statement. They may wish to reinterview one or more witnesses to confirm or clarify key points. While there may be inconsistencies in witnesses' statements, investigators should assemble the available testimony into a logical order. This information can then be analyzed along with data obtained at the accident site.

In an investigation, each investigator must bear in mind that not all people react in the same manner to a particular stimulus. For example, a witness involved in an accident may have an entirely different story from one who saw it at a distance. Some witnesses may also change their stories after they have discussed it with others; additional clues may be obtained by determining why the change was made.

A witness who has had a traumatic experience may not be able to recall the details of the accident. A witness who has a vested interest in the results of the investigation may offer biased testimony. Finally, eyesight, hearing, reaction time, and the general condition of each witness may affect his or her powers of observation. Entire sequences may be omitted because of a failure to observe them or because their importance was not realized.



In its simplest form, the scientific method involves the following sequence: making observations, developing hypotheses, and testing the hypotheses.

PROBLEM-SOLVING TECHNIQUES

Accidents represent problems that must be solved through investigations. Several formal procedures have been developed for solving problems of any degree of complexity. A number of these procedures are considered in this section.

The Scientific Method

The scientific method forms the basis of nearly all problem-solving techniques. It has been used for hundreds of years to conduct research. In its simplest form, it involves the following sequence: making observations, developing hypotheses, and testing the hypotheses.

Because even a simple research project may involve a large number of observations, a researcher records all observations immediately. A good investigator must do the same thing. Where possible, the observations should involve quantitative measurements. Quantitative data are often important in the subsequent development and testing of the hypotheses. Such measurements may require the use of a number of instruments in the field as well as in the laboratory.

When a number of observations have been made, the investigator develops one or more hypotheses that explain the observations. A hypothesis may explain only a few of the observations or it may attempt to explain all of them. At this stage, the hypothesis is merely a preliminary idea that must be tested. Even if it is rejected later, the investigator has a goal toward which to proceed.

The hypothesis is then tested against the original observations. A series of controlled experiments is often useful in performing this evaluation. If the hypothesis

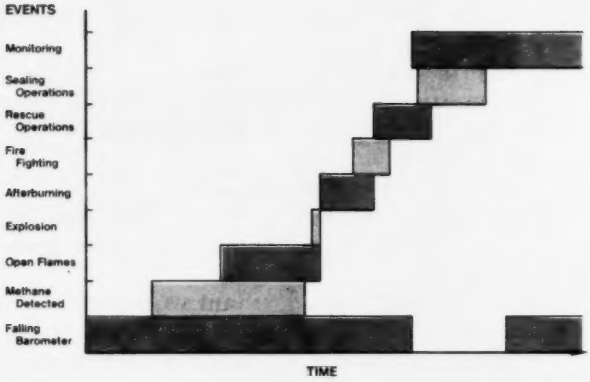
Where possible, observations should involve quantitative measurements. Such measurements may require the use of a number of instruments in the field as well as in the laboratory.

explains all of the observations, testing may be a simple process. If not, either additional observations are made, the hypothesis is modified, or additional hypotheses are developed.

As with scientific research, the most difficult part of any investigation is the formulation of meaningful hypotheses. The following three principles may be used to simplify this step:

1. **The principle of agreement.**
   An investigator uses this principle in an attempt to find one factor that can be associated with each observation.
2. **The principle of differences.**
   This principle is based on the idea that variations in observations are due only to differences in one or more factors.
3. **The principle of concomitant variation.**
   This principle is the most important because it combines the ideas of both of the preceding principles. In using this principle, the investigator is interested in the factors that are common as well as those that are different in the observations.

In using the scientific method, the investigator must be careful to eliminate personal bias, and he must be willing to consider a range of alternatives. Finally, he must recognize that accidents often result from the chance occurrence of factors that are too numerous to evaluate fully.



An example Gantt chart depicting events that may occur before, during, and after a methane-air explosion.

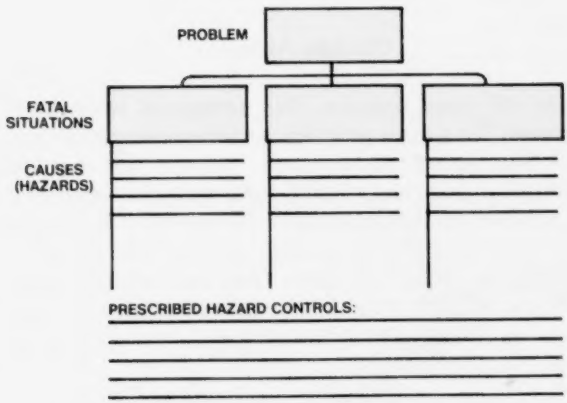
Change Analysis

As its name implies, this technique emphasizes change. To solve a problem, an investigator must look for deviations from the norm. As with the scientific method, change analysis also follows a logical sequence. It is based on the principle of differences described in the discussion of the scientific method. All problems are first considered to result from some unanticipated change. An analysis of the change is then made to determine its causes. The following steps are taken in using this method:

1. Define the problem (what happened?).
2. Establish the norm (what should have happened?).
3. Identify, locate, and describe the change (what, where, when, to what extent).
4. Specify what was and what was not affected.
5. Identify the distinctive features of the change.
6. List the possible causes.
7. Select the most likely causes.

Sequence Diagrams

Sequence diagrams such as Gantt charts can be used for scheduling investigative procedures. They can also assist in the development of the most probable sequence of events that led to the accident. Such a chart is especially useful in depicting events that occurred simultaneously.



A logic table is often used in a gross hazard analysis (GHA).

JSA	Occupation: _____	Specific Job: _____
Protective Apparel: _____		
JOB STEPS	HAZARDS	SAFE PROCEDURES

A sample Job Safety Analysis (JSA) chart. Job steps are listed in the first column. Hazards associated with each step are identified in the second column. Safe procedures or precautions are described in the third column.

Gross Hazard Analysis

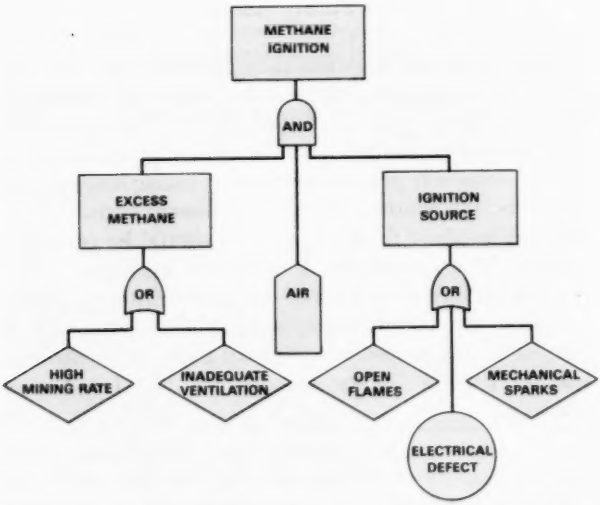
A gross hazard analysis (GHA) is generally performed to obtain a rough assessment of the risks involved in performing a task. It is called "gross" because it is usually refined with further study. It is thus particularly useful in the early stages of an accident investigation in developing hypotheses. A GHA will usually take the form of a logic diagram or table. In either case, it will contain a brief description of the problem or accident and a list of the situations that can lead to the problem. In some cases, these situations are analyzed a step further to determine how they could occur. A GHA diagram or table thus shows at a glance the potential causes of an accident. One of the following analysis techniques can then be used in the investigation to expand upon a GHA.

Job Safety Analysis

Job safety analysis (JSA) is part of many existing accident prevention programs. In general, JSA breaks a job into basic steps, identifies the hazards associated with each step, and prescribes controls for each hazard. A JSA is usually prepared as a chart listing these steps, hazards, and controls. If a JSA has been conducted for the job involved in an accident, it should be reviewed during the investigation. If one is not available, a JSA can be performed as part of the investigation to determine the events and conditions that led to the accident. Personnel interested in additional information on JSA should consult Safety Manual No. 5, "Job Safety Analysis."

Item	Failure Mode	Effects On		Probability, P	Severity, S	P x S	Remarks
		Other Items	Task				

A sample chart that can be used in failure mode and effect analysis (FMEA).



A generalized logic diagram that resulted from a fault tree analysis (FTA) of a methane ignition.

Failure Mode and Effect Analysis

Failure mode and effect analysis (FMEA) can be used in accident investigations to determine where failures occurred. All items used in the task involved in the accident are considered. These items include people, equipment, machine parts, materials, etc. In the usual procedure, each item is listed on an FMEA chart. The manner or mode in which each item can fail is also shown. The effects of each failure are then determined. Included here are the effects on other items and on overall task performance. In addition, evaluations are made concerning the risk associated with each failure. That is, projections are made regarding the probability of each failure and the severity of its effects. The most likely failures that led to the accident are then determined by comparing these projected effects and risks with actual accident results.

Fault Tree Analysis

In fault tree analysis (FTA), a logic diagram is constructed that shows all of the potential causes of an accident or other undesired event. The undesired event is shown at the top of a "tree." Reasoning backward from this event, all of the circumstances that can lead to it are determined. These circumstances are then broken down into the events that can lead to them, and so on. The process is continued until all events that can ultimately produce the undesired event are identified. Each of these events and the manner in which they combine are depicted on the logic tree. This information is then used to determine the most probable sequence of events that led to the accident. Additional information on FTA is provided in Safety Manual No. 8, "Fault Tree Analysis."

TYPICAL ACCIDENT REPORT FORM

1. Background Information: Date/Time of Accident

Day _____ Shift _____

Location _____

Name/Occupation/Activity of Injured _____

_____

Nature of Injury _____

Property Damage _____

Witnesses _____

2. Account of the Accident (What happened? Accident type)

_____

_____

_____

_____

3. Discussion: Direct Causes (Energy sources; Hazardous materials) _____

_____

Indirect Causes (Unsafe acts/conditions) _____

_____

Basic Causes (Management; Personal; Environmental) _____

_____

4. Recommendations: Immediate _____

_____

Long Range _____

_____

Investigated by _____ Date _____
(Signature)

Reviewed by _____ Date _____
(Signature)

Accident reports should include background information, an account of the accident, a discussion, and recommendations to prevent a recurrence.

REPORT OF INVESTIGATION

As noted earlier, an accident investigation is not complete until a report is prepared and submitted to the proper authorities. Special report forms are available in many cases. In other instances, a more extended report may be required. Such reports are often very elaborate and may include a cover page, a title page, an abstract, a table of contents, a commentary or narrative portion, a discussion of probable causes, and a section on conclusions and recommendations.

The following outline has been found especially useful in developing the information to be included in the formal report:

1. Background Information
   a. Where and when the accident occurred
   b. Who and what were involved
   c. Operating personnel and other witnesses
2. Account of the Accident (What happened?)
   a. Sequence of events
   b. Extent of damage
   c. Accident type
   d. Agency or source (of energy or hazardous material)
3. Discussion (Analysis of the Accident – **HOW; WHY**)
   a. Direct causes (energy sources; hazardous materials)
   b. Indirect causes (unsafe acts and conditions)
   c. Basic causes (management policies; personal or environmental factors)

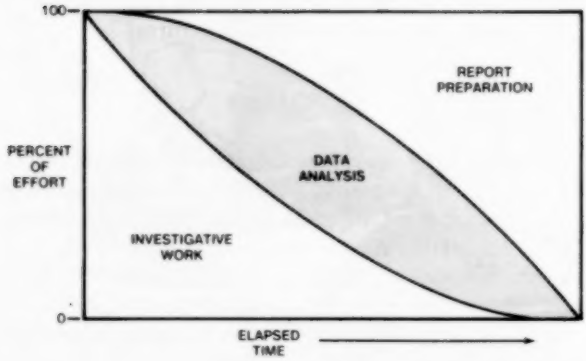
Responsible officials can use the information and recommendations that result from an accident investigation to prevent future accidents.

4. Recommendations (to prevent a recurrence) for immediate and long-range action to remedy:
   a. Basic causes
   b. Indirect causes
   c. Direct causes (such as reduced quantities or protective equipment or structures)

SUMMARY

Thousands of accidents occur daily throughout the United States. Generally, these result from a failure of people, equipment, supplies, or surroundings to behave as anticipated. A successful accident investigation determines not only **what** happened, but also finds **how** and **why** the accident occurred. Such investigations are conducted in an effort to prevent a similar or perhaps more disastrous sequence of events.

Most accident investigations follow a research technique called the scientific method. Facts are gathered and analyzed. Hypotheses are then developed to explain these facts. Each hypothesis is tested against the facts, and finally, the most probable explanation of the accident is selected. Any one of a number of problem-solving techniques based on this investigative approach may be used. An investigation is not complete, however, until a final report is submitted. Responsible officials can then use the resulting information and recommendations to prevent future accidents.



In practice, the investigative work, data analysis, and report preparation proceed simultaneously over much of the time spent on the investigation.

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An investigation is not complete until all data have been analyzed and a final report is prepared.

APPENDIX A — GLOSSARY

Accident—Any unplanned event that results in personal injury or in property damage.

Accident investigation—The process of determining how and why an accident occurred.

Fact—Something known to have happened; a truth known by actual experience or observation.

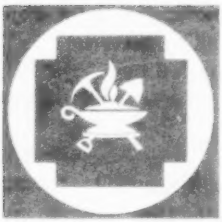
Hazard—Any condition that may result in, or contribute to, an accident.

Hypothesis—A theory proposed as an explanation of a set of facts.

Incident—Any unplanned event that adversely affects the completion of a task.

Risk—A measure of the probability of occurrence of a particular event of specified severity.

Witness—One who personally observes the occurrence of a particular event.



APPENDIX B — ACCIDENT TYPES

1. Fall to
    - same level
    - lower level
2. Caught
    - in
    - on
    - between
3. Contact with
    - acid
    - electricity
    - heat
    - caustic
    - cold
    - radiation
    - toxic and noxious substances
4. Overexertion
    - lifting
    - pulling
    - pushing
5. Struck
    - against
        - stationary or moving object
        - protruding object
        - sharp or jagged edge
    - by
        - moving or flying object
        - falling material
6. Rubbed or abraded by
    - friction
    - pressure
    - vibration
7. Bodily reaction from
    - voluntary motion
    - involuntary motion

APPENDIX C — DIRECT CAUSES OF ACCIDENTS

Energy Sources

1. Mechanical
   - machinery
   - tools
   - moving objects
   - compressed gases
   - explosives
   - strain (self)
2. Electrical
   - uninsulated conductors
   - high voltage sources
3. Chemical
   - acids
   - bases
   - fuels
   - reactive materials
4. Thermal
   - flammable
   - non-flammable
5. Radiation
   - noise
   - lasers
   - microwaves
   - x-rays
   - radioactive materials

Hazardous Materials

1. Compressed or liquified gas
   - flames
   - hot surfaces
2. Corrosive material
3. Flammable material
   - solid
   - liquid
   - gas
4. Oxidizing material
5. Poison
6. Radioactive material
7. Etiological agent
8. Dust
9. Explosive

APPENDIX D — INDIRECT CAUSES OF ACCIDENTS

Unsafe Acts

1. Failing to use personal protective equipment
2. Failing to warn co-workers or to secure equipment
3. Engaging in horseplay
4. Lifting improperly
5. Loading or placing equipment or supplies improperly
6. Making safety devices inoperable
7. Operating equipment at improper speeds
8. Operating equipment without authority
9. Servicing equipment in motion
10. Taking an improper working position
11. Using alcoholic beverages
12. Using drugs
13. Using defective equipment
14. Using equipment improperly

Unsafe Conditions

1. Congestion of workplace
2. Defective tools, equipment, or supplies
3. Excessive noise
4. Fire and explosion hazards
5. Hazardous atmospheric conditions
   - gases
   - dusts
   - fumes
   - vapors
6. Inadequate supports or guards
7. Inadequate warning systems
8. Poor housekeeping
9. Poor illumination
10. Poor ventilation
11. Radiation exposure

APPENDIX E —
BASIC CAUSES OF ACCIDENTS

Management Safety Policies and Decisions

1. Health and safety policy is not:
   - In writing
   - Signed by top management
   - Distributed to each employee
   - Reviewed periodically
2. Health and safety procedures do not provide for
   - A written manual
   - Safety meetings
   - Adequate housekeeping
   - Preventive maintenance
   - Safety inspections
   - Accident investigations
   - Job safety analysis
   - Medical surveillance
   - Reports
3. Health and safety is not considered in the procurement of:
   - Supplies
   - Equipment
   - Services
4. Inadequate personnel practices regarding:
   - Employee selection
   - Training
   - Assignment
   - Job observation
   - Communications
   - Assigned responsibility
   - Accountability

Personal Factors

1. Behavior factors:
   - Accident repeater
   - Risk taking
   - Lack of hazard awareness
2. Experience factors:
   - Insufficient knowledge
   - Inadequate skills
   - Accident record
   - Unsafe practices

3. Physical factors:
    - Size
    - Strength
    - Stamina
4. Mental factors:
    - Emotional instability
    - Depression
    - Alcoholism
    - Drug use
5. Motivational factors:
    - Needs
    - Capabilities
6. Attitude factors:
    - People
    - Company
    - Job

Environmental Factors

1. Unsafe facility designs:
    - Mechanical layout
    - Electrical systems
    - Hydraulic systems
    - Air conditioning
    - Access ways
    - Material handling
    - Illumination
    - Noise
2. Unsafe operating procedures:
    - Normal
    - Emergency
3. Unsafe projections:
    - Physical plant
    - Equipment
    - Supplies
    - Procedures
4. Unsafe location factors:
    - Geographic area
    - Terrain
    - Surroundings
    - Access roads
    - Weather

ABOUT THE AUTHORS

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Safety Manuals

Coal Mining

Mine Gases

First Aid

Accident Prevention

Laboratory Safety

Job Safety Analysis

Heat Stress in Mining

The Radiation Hazard in Mining

Fault Tree Analysis

Electrical Hazards

Accident Investigation

Dust Diseases in Mining

Coal Mine Maps

Personal Protective Equipment

System Safety Engineering